

J/ψ absorption in a multicomponent hadron gas

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Abstract. A model for anomalous J/Ψ suppression in high energy heavy ion collisions is presented. As the additional suppression mechanism beyond standard nuclear absorption inelastic J/Ψ scattering with hadronic matter is considered. Hadronic matter is modeled as an evolving multi-component gas of point-like non-interacting particles (MCHG). Estimates for the sound velocity of the MCHG are given and the equation of state is compared with Lattice QCD data in the vicinity of the deconfinement phase transition. The approximate cooling pattern caused by longitudinal expansion is presented. It is shown that under these conditions the resulting J/Ψ suppression pattern agrees well with NA38 and NA50 data.

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1. INTRODUCTION

The possible existence of a quark-gluon plasma (QGP) phase of highly excited hadronic matter is one of the most intriguing questions of high energy physics discussed since almost three decades up to now. This novel state of matter has been also predicted in lattice QCD calculations (for a review see [1] and references therein) and the critical temperature T_c for the ordinary hadronic matter-QGP phase transition has been obtained in the range of 150 - 270 MeV depending on the number of active quark flavors (this corresponds to the broad range of the critical energy densities $\epsilon_c \simeq 0.26 - 5.5$ GeV/fm³). Since estimates of the NA50 collaboration for the energy density obtained in the central rapidity region (CRR) give the value of 3.5 GeV/fm³ for the most central Pb-Pb data point, it has been argued that the conditions for the existence of the QGP are met in Pb-Pb collisions at CERN SPS [2].

The main argument for the QGP creation during Pb-Pb collisions at the CERN SPS was the observation of the anomalous suppression of J/Ψ relative yield. J/Ψ suppression as a signal for the QGP formation was originally proposed by Matsui and Satz [3]. The idea is based on the modification of the quark forces in plasma due to color screening which would entail a dissociation of $c - \bar{c}$ bound states, including the prominent J/Ψ at high temperature, observable as a significant depletion of the dilepton spectrum around the quarkonium invariant mass.

The key point of the NA50 Collaboration paper [2] was the figure, denoted as

Fig.6 there, where experimental data for Pb-Pb collision values of $\frac{B_{\mu\mu}\sigma_{J/\psi}}{\sigma_{DY}}$ (the ratio of the J/Ψ to the Drell-Yan production cross-section times the branching ratio of the J/Ψ into a muon pair) were presented together with some conventional predictions. Here, "conventional" meant that J/Ψ suppression was due to J/Ψ absorption in ordinary hadronic matter. Since all those conventional curves saturated at high transverse energy E_T , but the experimental data fell from $E_T \simeq 90$ GeV much lower and this behavior could be reproduced on the base of J/Ψ disintegration in the QGP [4], this was argued to be circumstantial evidence for QGP formation in most central Pb-Pb collisions. In general, the immediate reservation about such reasoning was that besides those already known (see e.g. [6, 7, 8, 9, 10, 11] and references [12-15] in [2]), other possible models formulated in terms of hadronic degrees of freedom could not be ruled out as long as the J/Ψ absorption rates in dense hadronic matter are largely unknown.

Within a few years the NA50 Collaboration has updated their J/Ψ results [12], using the nuclear absorption systematics obtained from precise pA results. It appeared that also these data could be explained with a hadronic comover absorption model [13], without the necessity to invoke QGP formation. The question, however, arises whether the inputs used in these models are consistent with accessible theoretical or experimental information.

In the present contribution, we present a systematic step towards and general description of J/Ψ absorption in the framework of a statistical analysis which can provide a baseline in the search for non-hadronic explanations of anomalous J/Ψ suppression.

The main features of the model introduced in Ref. [5] are

1. a multi-component non-interacting hadron gas appears in the CRR instead of the QGP. All hadrons from the lowest up to Ω^- baryon (with their non-zero masses) are taken into account as constituents of the matter;
2. the gas expands longitudinally and transversely;
3. J/Ψ suppression is the result of inelastic scattering on constituents of the gas and on nucleons of colliding ions. Both "traditional" sources of J/Ψ suppression, namely absorption in the nuclear matter and in the hadron gas in the CRR, are considered simultaneously.

The model has the following parameters: the initial time t_0 , the J/Ψ -baryon cross section σ_b , the initial baryon number density n_B^0 , r_0 in the expression $R_A = r_0 A^{\frac{1}{3}}$ and the freeze-out temperature $T_{f.o.}$. But the last quantity disappears effectively in the final estimations because the "natural" freeze-out is enforced by the transverse expansion when the rarefaction wave reaches the collision axis.

2. THE TIMETABLE OF EVENTS IN THE CRR

For a given A-B collision $t = 0$ is fixed at the moment of the maximal overlap of the nuclei (for more details see *e.g.* [10]). As the nuclei pass each other charmonium states are produced as the result of gluon fusion. After half of the time the nuclei

need to cross each other ($t \sim 0.5$ fm), matter appears in the CRR. It is assumed that the matter thermalizes almost immediately and the moment of thermalization, t_0 , is estimated to about 1 fm/c [10, 14]. Then the matter begins its expansion and cooling and after reaching the freeze-out temperature, $T_{f.o.}$, it ceases as a thermodynamical system. The moment when the temperature has decreased to $T_{f.o.}$ is denoted as $t_{f.o.}$. Since the matter under consideration is a gas of hadronic resonances, no phase transition takes place during cooling.

For the description of the evolution of the matter, relativistic hydrodynamics is employed. The longitudinal component of the solution of the hydrodynamic equations (the exact analytic solution for an (1+1)-dimensional case) reads (for details see, e.g., [14, 15])

$$s(\tau) = \frac{s_0 \tau_0}{\tau}, \quad n_B(\tau) = \frac{n_B^0 \tau_0}{\tau}, \quad v_z = \frac{z}{t} \quad (1)$$

where $\tau = \sqrt{t^2 - z^2}$ is a local proper time, v_z is the component of the fluid velocity parallel to the collision axis and s_0 and n_B^0 are the initial densities of the entropy and the baryon number, respectively. For $n_B = 0$ and the uniform initial temperature distribution with a sharp edge at the border established by the nuclear surfaces, the full solution of the (3+1)-dimensional hydrodynamic equations is known [16]. The evolution derived is decomposed into the longitudinal expansion inside a slice bordered by the front of the rarefaction wave and the transverse expansion which is superimposed outside the wave. Since small but nevertheless non-zero baryon number densities are considered here, the above-mentioned description of the evolution has to be treated as an assumption in the presented model. The rarefaction wave moves radially inward with the sound velocity c_s (see Sect. 4).

3. THE MULTI-COMPONENT HADRON GAS

For an ideal multicomponent hadron gas in thermal and chemical equilibrium, consisting of l species (here, mesons are considered up to K_2^* and baryons up to Ω^-), energy density ϵ , baryon number density n_B , strangeness density n_S and entropy density s are given by ($\hbar = c = 1$ always)

$$\epsilon = \frac{1}{2\pi^2} \sum_{i=1}^l (2s_i + 1) \int_0^\infty dp \frac{p^2 E_i}{\exp\left\{\frac{E_i - \mu_i}{T}\right\} + g_i}, \quad (2)$$

$$n_B = \frac{1}{2\pi^2} \sum_{i=1}^l (2s_i + 1) \int_0^\infty dp \frac{p^2 B_i}{\exp\left\{\frac{E_i - \mu_i}{T}\right\} + g_i}, \quad (3)$$

$$n_S = \frac{1}{2\pi^2} \sum_{i=1}^l (2s_i + 1) \int_0^\infty dp \frac{p^2 S_i}{\exp\left\{\frac{E_i - \mu_i}{T}\right\} + g_i}, \quad (4)$$

$$s = \frac{1}{6\pi^2 T^2} \sum_{i=1}^l (2s_i + 1) \int_0^\infty dp \frac{p^4}{E_i} \frac{(E_i - \mu_i) \exp\left\{\frac{E_i - \mu_i}{T}\right\}}{\left(\exp\left\{\frac{E_i - \mu_i}{T}\right\} + g_i\right)^2}, \quad (5)$$

where $E_i = (m_i^2 + p^2)^{1/2}$ and m_i , B_i , S_i , μ_i , s_i and g_i are the mass, baryon number, strangeness, chemical potential, spin and a statistical factor of species i , respectively (an antiparticle is treated as a different species). The chemical potential $\mu_i = B_i\mu_B + S_i\mu_S$ defines that of the overall baryon number, μ_B and that of strangeness, μ_S .

To obtain the time dependence of temperature, baryon number and strangeness chemical potentials one has to solve the equations (3) - (5) numerically with s , n_B and n_S given as time dependent quantities. For $s(\tau)$ and $n_B(\tau)$ the expressions (1) are taken and $n_S = 0$ since the overall strangeness equals zero during the whole evolution, see Sect. 5.

4. THE SOUND VELOCITY IN THE MCHG

In the hadron gas the sound velocity squared is given by the standard expression

$$c_s^2 = \frac{\partial P}{\partial \epsilon} . \quad (6)$$

Since the experimental data for heavy-ion collisions suggest that the baryon number density is non-zero in the CRR at AGS and SPS energies [17, 18, 19], we calculate the above derivative for various values of n_B [20, 21].

To estimate initial baryon number density n_B^0 we can use experimental results for S-S [17] or Au-Au [18, 19] collisions. In the first approximation we can assume that the baryon multiplicity per unit rapidity in the CRR is proportional to the number of participating nucleons. For S-S collisions we have $dN_B/dy \cong 6$ [17] and 64 participating nucleons. For central collisions of lead nuclei we can estimate the number of participating nucleons as $2A = 416$, so we have $dN_B/dy \cong 39$. Having taken the initial volume in the CRR equal to $\pi R_A^2 \cdot 1$ fm, we arrive at $n_B^0 \cong 0.25$ fm⁻³. This is some underestimation because for S-S collisions the beam energy was at 200 GeV/nucleon, whereas for Pb-Pb at 158 GeV/nucleon. From the Au-Au data extrapolation one can estimate $n_B^0 \cong 0.65$ fm⁻³ [18]. These values are for central collisions. So, we estimate (6) for $n_B = 0.25$, 0.65 fm⁻³ and additionally, to investigate the dependence on n_B much carefully, for $n_B = 0.05$ fm⁻³. The results of the numerical evaluation of (6) are presented in Fig. 1. For comparison, we show also curves for $n_B = 0$ and for a pure massive pion gas. These curves are taken from [20].

The "physical region" we consider between 100 and 200 MeV on the temperature axis. This is because the critical temperature for the possible QGP-hadronic matter transition is of the order of 200 MeV [1] and the freeze-out temperature should not be lower than 100 MeV [18]. At low temperatures we can see a completely different behaviour of the cases with $n_B = 0$ and $n_B \neq 0$. We think that this is caused by the fact that for $n_B \neq 0$ the gas density can not reach zero when $T \rightarrow 0$, whereas for $n_B = 0$ it can. For the higher temperatures all curves excluding the pion case behave qualitatively in the same way. From $T \approx 70$ MeV they decrease to their minima (for $n_B = 0.65$ fm⁻³ at $T \cong 219.6$ MeV, for $n_B = 0.25$ fm⁻³ at $T \cong 202.5$

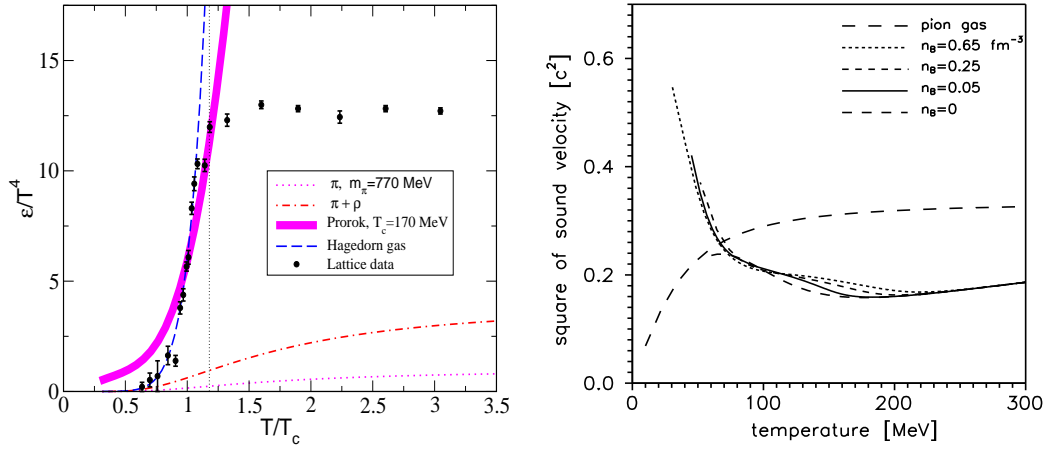


FIGURE 1. Left panel: Energy density in units of T^4 versus scaled temperature T/T_c for the present hadron resonance gas model [5] compared with the QCD Lattice data [22] and the Hagedorn resonance gas with scaled hadron masses to adapt for the case of unphysical quark masses in the Lattice simulation [23]. Right panel: Dependence of the sound velocity squared on temperature for $n_B = 0.65 \text{ fm}^{-3}$ (short-dashed), $n_B = 0.25 \text{ fm}^{-3}$ (dashed), $n_B = 0.05 \text{ fm}^{-3}$ (solid) and $n_B = 0$ (long-dashed). The case of the pure pion gas (long-long-dashed) is also presented.

MeV, for $n_B = 0.05 \text{ fm}^{-3}$ at $T \cong 183.4$ MeV and for $n_B = 0$ at $T \cong 177.3$ MeV) and then they increase to merge to each other above $T \approx 250$ MeV.

5. THE COOLING PATTERN VS. SOUND VELOCITY

In Sect. 3 we have explained how to obtain the time dependence of the temperature of the longitudinally expanding hadron gas. This dependence proved to be very well approximated by the expression [20, 21]

$$T(\tau) \cong T_0 \cdot \tau^{-a} . \quad (7)$$

The above approximation is valid in the temperature range $[T_{f.o.}, T_0]$, where $T_{f.o.} \geq 100$ MeV, $T_0 \leq T_{0,max}$ and $T_{0,max} \approx 230$ MeV. We started from T_0 equal to 227.2 MeV (for $n_B^0 = 0.65 \text{ fm}^{-3}$), 229.3 MeV (for $n_B^0 = 0.25 \text{ fm}^{-3}$) and 229.7 MeV (for $n_B^0 = 0.05 \text{ fm}^{-3}$). These values correspond to $\epsilon_0 = 5.0 \text{ GeV/fm}^3$ (the initial energy density in the CRR has been estimated by NA50 [2] to $\epsilon_0 = 3.5 \text{ GeV/fm}^3$). Then we took several decreasing values of $T_0 < T_{0,max}$. For every T_0 chosen we repeat the procedure of obtaining the approximation (7), i.e. the coefficient a of the power law.

We can formulate the following conclusion: in the "physical region" of temperature and for realistic baryon number densities, the longitudinal expansion given by (1) results in the cooling of the hadron gas described by (7) with $a = c_s^2(T_0)$, namely:

$$T(\tau) \cong T_0 \cdot \left(\frac{\tau_0}{\tau} \right)^{c_s^2(T_0)} \quad (8)$$

where T_0 belongs to the "physical region". Note that $T(\tau) = T_0 \cdot \left(\frac{\tau_0}{\tau}\right)^{c_s^2}$ is the exact expression for a baryonfree gas with the sound velocity constant (for details see [15, 16]). It should be stressed that c_s^2 in (8) is constant depending only on the initial temperature T_0 from which the cooling starts. The approximation (8) will be used to simplify the evaluation of the J/Ψ survival factors in the next sections.

It should be added that for the excluded volume hadron gas model the above-mentioned conclusion is no longer valid. We performed the appropriate simulations, but approximations of $T(\tau)$ by a power law turned out to be rather inaccurate and yielded a coefficient a which was by a factor two smaller than the squared velocity of sound.

6. J/Ψ ABSORPTION IN THE EXPANDING MCHG

As it has been already mentioned in Sect. 2, charmonium states are produced in the beginning of the collision, when nuclei overlap. For simplicity, it is assumed that the production of $c\bar{c}$ states takes place at $t = 0$. To describe J/Ψ absorption quantitatively, the idea of Ref. [10] is generalized here to the case of the multi-component massive gas. Since in the CRR longitudinal momenta of particles are much lower than transverse ones (in the c.m.s. frame of nuclei), the J/Ψ longitudinal momentum is put to zero. Additionally, only the plane $z = 0$ is under consideration. For the simplicity of the model, it is assumed that all charmonium states are completely formed and can be absorbed by constituents of the surrounding medium from the moment of their creation by inelastic scattering through interactions of the type

$$c\bar{c} + h \longrightarrow D + \bar{D} + X, \quad (9)$$

where h denotes a hadron, D is a charm meson and X stands for a particle which is necessary to conserve the charge, baryon number or strangeness.

Since Pb-Pb collisions are the most relevant case for the problem of QGP search (see remarks in Sect. 1), the further considerations are done for this case.

It is assumed that the hadron gas, which appears in the space between the nuclei after they have crossed each other, also has the shape of the overlap area of the colliding nuclei (S_{eff}) at t_0 in the $z = 0$ plane. Then, the transverse expansion starts as a rarefaction wave moving inward S_{eff} at t_0 . From the considerations based on the relativistic kinetic equation (for details see [5, 10]), the survival fraction of J/Ψ in the hadron gas as a function of the initial energy density ϵ_0 in the CRR is obtained:

$$\mathcal{N}_{h.g.}(\epsilon_0) = \int dp_T g(p_T, \epsilon_0) \cdot \exp \left\{ - \int_{t_0}^{t_{final}} dt \sum_{i=1}^l \int \frac{d^3 \vec{q}}{(2\pi)^3} f_i(\vec{q}, t) \sigma_i v_{rel,i} \frac{p_\nu q_i^\nu}{E E'_i} \right\}, \quad (10)$$

where the sum is over all species of scatters (hadrons), $p^\nu = (E, \vec{p}_T)$ and $q_i^\nu = (E'_i, \vec{q})$ are four momenta of J/Ψ and hadron species i respectively, σ_i stands for the absorption cross-section of $J/\Psi - h_i$ scattering, $v_{rel,i}$ is the relative velocity of J/Ψ and hadron h_i . M and m_i denote J/Ψ and h_i masses respectively ($M = 3097$ MeV).

The function $g(p_T, \epsilon_0)$ is the J/Ψ initial momentum distribution. It has a gaussian form and reflects gluon multiple elastic scattering on nucleons before their fusion into a J/Ψ in the first stage of the collision [25, 26, 27]. The upper limit t_{final} of the time integration in (10) is the minimal value of $\langle t_{esc} \rangle$ and $t_{f.o.}$. The quantity $\langle t_{esc} \rangle$ is the average time of the escape of J/Ψ 's from the hadronic medium for given values of b and J/Ψ velocity $\vec{v} = \vec{p}_T/E$. Note that the average is taken with the weight

$$p_{J/\Psi}(\vec{r}) = T_A(\vec{r})T_B(\vec{r} - \vec{b})/T_{AB}(b) , \quad (11)$$

where $T_{AB}(b) = \int d^2\vec{s} T_A(\vec{s})T_B(\vec{s} - \vec{b})$, $T_A(\vec{s}) = \int dz \rho_A(\vec{s}, z)$ and $\rho_A(\vec{s}, z)$ is the nuclear matter density distribution taken here as the Woods-Saxon form with parameters from [28]. In the integration over hadron momentum in (10) the threshold for the reaction (9) is included, i.e. σ_i equals zero for $(p^\nu + q_i^\nu)^2 < (2m_D + m_X)^2$ and is constant elsewhere (m_D is a charm meson mass, $m_D = 1867$ MeV). Also the usual Bose-Einstein or Fermi-Dirac distribution for hadron species i is used in (10)

$$f_i(\vec{q}, t) = f_i(q, t) = (2s_i + 1) \left\{ \exp \left[\frac{E'_i - \mu_i(t)}{T(t)} \right] + g_i \right\}^{-1} . \quad (12)$$

For simplicity, we use (8) as the approximation to $T(t)$ in (12) and $\mu_B(t)$ and $\mu_S(t)$ are solutions of only two equations (3) and (4) with T given by (8), $n_B(t)$ by (1) and $n_S(t) = 0$.

As far as σ_i is concerned, there are no data for every particular $J/\Psi - h_i$ scattering. Therefore, we use here universal, energy independent cross sections for scattering of charmonia on baryons, σ_b , and on mesons, $\sigma_m = 2\sigma_b/3$, according to the quark counting rules.

As it has been already suggested [7] also J/Ψ scattering in nuclear matter should be included in any J/Ψ absorption model. This could be done with the introduction of a J/Ψ survival factor in nuclear matter [30]

$$\mathcal{N}_{n.m.}(\epsilon_0) \cong \exp \left\{ -\sigma_{J/\psi N} \rho_0 L \right\} , \quad (13)$$

where ρ_0 is the nuclear matter density and L the mean path length of the J/Ψ through the colliding nuclei obtained according to

$$\rho_0 L(b) = \frac{1}{2T_{AB}} \int d^2\vec{s} T_A(\vec{s})T_B(\vec{s} - \vec{b}) \left[\frac{A-1}{A} T_A(\vec{s}) + \frac{B-1}{B} T_B(\vec{s} - \vec{b}) \right] . \quad (14)$$

Since the J/Ψ absorption processes in nuclear matter and in the MCHG are separated in time, the J/Ψ survival factor for a heavy-ion collision with the initial energy density ϵ_0 , could be defined as

$$\mathcal{N}(\epsilon_0) = \mathcal{N}_{n.m.}(\epsilon_0) \cdot \mathcal{N}_{h.g.}(\epsilon_0) . \quad (15)$$

Note that since the right hand sides of Eqs. (10) and (13) include parts which depend on the impact parameter b and the left hand sides are functions of ϵ_0 only, the expression converting the first quantity to the second (or reverse) should be

defined. This is done with the use of the dependence of ϵ_0 on the transverse energy E_T extracted from NA50 data [2] (for details see [5]).

To make the model as realistic as possible, one should keep in mind that only about 60% of the observed J/Ψ 's are directly produced during the collision. The remainder is the result of χ ($\sim 30\%$) and ψ' ($\sim 10\%$) decays. Therefore the realistic J/Ψ survival factor could be expressed as

$$\mathcal{N}(\epsilon_0) = 0.6\mathcal{N}_{J/\psi}(\epsilon_0) + 0.3\mathcal{N}_\chi(\epsilon_0) + 0.1\mathcal{N}_{\psi'}(\epsilon_0), \quad (16)$$

where $\mathcal{N}_{J/\psi}(\epsilon_0)$, $\mathcal{N}_\chi(\epsilon_0)$ and $\mathcal{N}_{\psi'}(\epsilon_0)$ are given also by Eqs. (10), (13) and (15) but with $g(p_T, \epsilon_0)$, $\sigma_{J/\psi N}$ and M changed appropriately (for details see [5]).

7. RESULTS

Now we can complete the calculations of formula (10) for values of n_B^0 given in Sect. 4. The last parameter of the model is the freeze-out temperature. Two values $T_{f.o.} = 100, 140$ MeV are taken here and they agree well with estimates based on hadron yields [18]. The main results are presented in Fig. 2. The original data [2] for $B_{\mu\mu}\sigma_{J/\psi}^{PbPb}/\sigma_{DY}^{PbPb}$ and J/Ψ survival factors given by (16) multiplied by $B_{\mu\mu}\sigma_{J/\psi}^{pp}/\sigma_{DY}^{pp}$ as functions of E_T are depicted there (for details see [5]). When comparing the

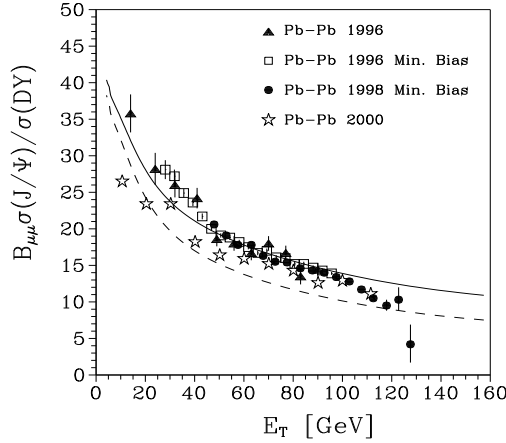


FIGURE 2. J/Ψ survival factor times $B_{\mu\mu}\sigma_{J/\psi}^{pp}/\sigma_{DY}^{pp}$ in the longitudinally and transversely expanding hadron gas for the Woods-Saxon nuclear matter density distribution and $n_B^0 = 0.25 \text{ fm}^{-3}$, $T_{f.o.} = 140$ MeV, $c_s = 0.45$ and $r_0 = 1.2$ fm. The curves correspond to $\sigma_b = 4$ mb (solid) and $\sigma_b = 5$ mb (dashed). The black triangles represent the 1996 NA50 Pb-Pb data, the white squares the 1996 analysis with minimum bias, the black points the 1998 analysis with minimum bias [2], and the white stars to the 2000 NA50 Pb-Pb reanalyzed data [12].

present model with the data from the NA50 collaboration in Fig. 2, we want to focus on the region below $E_T \sim 100$ GeV, which corresponds to initial energy densities below $\epsilon_0 \sim 3.0 \text{ GeV/fm}^3$ ($T_0 < 210$ MeV), where the MCHG gives an acceptable description of the equation of state for hot and dense matter, in agreement with lattice QCD data, see the left panel of Fig. 1. In our phenomenological analysis shown in Fig. 2, we assume universal cross sections for mesons and baryons, with

the appropriate thresholds for their dissociation reactions but energy-independent, $\sigma_b = 4$ mb (solid line) and 5 mb (dashed line). Note that the solid line perfectly describes the data between the onset of the deviation from the nuclear absorption baseline at $E_T \sim 40$ GeV and the limit of applicability of the MCHG picture at $E_T \sim 100$ GeV. Does this result disprove the claim of the NA50 collaboration that the onset of anomalous suppression at $E_T \sim 40$ GeV is evidence for the creation of a new form of matter, made of deconfined quarks and gluons (QGP) in this experiment?

Such a claim would be premature. The weak point is the question about the charmonium dissociation cross sections. Although the absorption cross section for J/ψ in cold nuclear matter has been measured in pA collisions by the NA50 experiment to be $\sigma_{J/\psi N} = 4.2 \pm 0.5$ mb [31], this may be a result of the downfeeding from χ_c and ψ' with larger cross sections, so that the “true” absorption cross section for the ground state component is between 2 and 3 mb, see also [32]. No experimental information for the charmonia absorption cross sections on higher baryonic resonances or on mesons is available yet.

However, there is progress in theoretical approaches. Based on a diagrammatic approach to quark exchange processes in hadron-hadron scattering [33], the dissociation cross section for charmonia on mesons have been calculated [34] to have a sharp rise at threshold to maxima between 1 and 10 mb, depending on the channel, followed by a fast decrease in energy due to vanishing overlap integrals between asymptotic mesonic states. A recent calculation within a fully relativistic approach has confirmed the result for J/ψ dissociation by pion impact [35]. Similar calculations for baryon impact [36] show that both assumptions made in this work could be disproved: the universality and energy independence.

8. CONCLUSIONS

Properties of the hadron resonance gas model under conditions reached in the ultrarelativistic heavy ion experiments are very close to the phase transition region estimated from the lattice simulation data, see Fig. 1. We have shown that with J/Ψ absorption cross sections on hadrons of 4 mb, an overall satisfactory description of NA38/NA50 data on J/Ψ suppression could be given here. Therefore, one could argue that the NA50 Pb-Pb data do not provide evidence for the production of *deconfined* matter in the central rapidity region of a Pb-Pb collision.

It is an interesting task for forthcoming work to use those energy dependent, non-universal cross sections of the quark exchange model in the calculation of charmonium dissociation in the MCHG model. We expect that the outcome of such a calculation will leave room for the discussion of in-medium modification (increase) of dissociation rates by changes in the spectrum (broadening) of the final state open charm hadrons which determine (effectively lower) the reaction thresholds. Examples have been given for the $\pi - \rho$ gas [37] and for nuclear matter [38]. A heuristic extension of the MCHG to include spectral broadening due to the Mott dissociation of hadrons (Mott-Hagedorn resonance gas) has been given in [39], but deserves a microscopic foundation. Therefore, we conclude that the

hadronic absorption cross sections of the J/Ψ need to be determined to a higher accuracy before the anomalous J/Ψ suppression could be interpreted as a good signal for QGP formation in central heavy-ion collisions.

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